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**GAMMA RAYS FROM THE
MAGELLANIC CLOUDS**

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Gamma Rays from the Magellanic Clouds

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Several years ago, Ginzburg¹ suggested that γ -radiation from the Magellanic clouds would provide a test for the metagalactic cosmic ray origin hypothesis. He pointed out that if cosmic rays fill the Magellanic clouds at the same intensity as observed in the solar galactic neighborhood, γ -rays should be produced in the Magellanic Clouds from cosmic ray interactions with neutral hydrogen gas in the Clouds as observed in 21cm surveys. Ginzburg further argued that if the γ -ray fluxes were below these nominal values, $2 \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1}$ above 100 MeV for the Large Magellanic Cloud (LMC) and $1 \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1}$ above 100 MeV for the Small Magellanic Cloud (SMC), the extragalactic origin hypothesis would be disproved since the cosmic ray flux would be below the expected value.

The purpose of this letter is to point out that, on the contrary, the γ -ray fluxes from the Magellanic Clouds would, most probably, be significantly above these values, particularly if cosmic rays are galactic in origin, because in this case they would be generated in the Clouds themselves. Indeed, the fluxes would be high enough to be detectable by the presently operational COS-B satellite.

Firstly, we recompute Ginzburg's nominal fluxes for the Clouds using somewhat updated parameters. For the distance to the Clouds, we adopt the following values²

$$\begin{aligned} R_{\text{LMC}} &= 60.5 \text{ kpc} \\ R_{\text{SMC}} &= 74 \text{ kpc} \end{aligned} \tag{1}$$

The masses of HI in the Clouds are then obtained by using the value given by McGee and Milton³ for the LMC and that of Hindman⁴ for the SMC and correcting for the revised distance scales.

$$\begin{aligned} M_{\text{LMC}}^{\text{HI}} &= 6.5 \times 10^8 M_{\odot} \\ M_{\text{SMC}}^{\text{HI}} &= 7.3 \times 10^8 M_{\odot} \end{aligned} \tag{2}$$

Using these values, the mass of HI gas expressed as fractions of the total masses of the Clouds are

$$\begin{aligned} (M_{\text{HI}}/M_{\text{T}})_{\text{LMC}} &\simeq 0.07 \\ (M_{\text{HI}}/M_{\text{T}})_{\text{SMC}} &\simeq 0.39 \end{aligned} \tag{3}$$

This can be compared to the value for our Galaxy⁵ of

$$(M_{\text{HI}}/M_{\text{T}})_{\text{GAL}} \simeq 0.02 \tag{4}$$

Because of their proximity and relatively high gas content (see eqs. (3) and (4)), the Magellanic Clouds make ideal candidate γ -ray sources. Using the values given in equations (1) and (2), the nominal values (cf. Ref. 1) for fluxes from the clouds would be

$$\begin{aligned} \bar{F}_{\text{LMC}} &\simeq 2.1 \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1} \\ \text{and } \bar{F}_{\text{SMC}} &\simeq 1.6 \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1} \end{aligned} \tag{5}$$

However the expected fluxes, based on the galactic origin hypothesis may be factor of 4 higher, i.e.,

$$\begin{aligned} F_{\text{LMC}}^{\text{exp}} &= 8.4 \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1} \\ F_{\text{SMC}}^{\text{exp}} &= 6.4 \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1} \end{aligned} \tag{6}$$

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The reasons for this assertion stem from concepts relating galactic γ -ray production to molecular clouds and other Population I phenomena in our Galaxy.⁶⁻¹⁰ In this picture, cosmic-rays are produced as the result of supernova explosions of massive Population I stars which evolve out of the cloud complexes which lead to the formation of OB associations. The presence of strong Population I components in both the LMC and SMC is evidenced by large amounts of gas, gas-dust complexes associated with HII regions, the most spectacular of which is 30 Doradus in the LMC, and the presence of supernova remnants and shells and non-thermal radio sources in both Clouds.¹¹ It thus seems reasonable to assume that the Magellanic Clouds contain as much gas in the form of H_2 as in atomic form and that this gas may be associated with a flux of cosmic rays generated within the Clouds themselves. The LMC appears to be particularly rich in gas and dust. In view of the fact that the γ -ray emissivity of our Galaxy is an order of magnitude higher than the nominal value in a ring between 5 and 6 kpc from the galactic center where the Population I activity of our Galaxy is highest^{9,10}, the postulated factor of 4 increase in predicted flux for the Magellanic Clouds, while very uncertain, seems reasonable. A factor of 2 would be accounted for alone by including an H_2 component of interstellar gas and another factor of at least 2 in cosmic ray intensity is exhibited in our own Galaxy in regions of high Population I activity.

An interesting outgrowth of this discussion is the possible test between two different interpretations of the galactic γ -ray emission. While one school of thought attributes this enhancement in galactic emission in the inner Galaxy to increases in gas and cosmic-ray sources

alone,⁶⁻¹⁰ another school of thought holds that this enhancement is produced by the trapping of cosmic rays in spiral arms¹²⁻¹⁴. Since spiral structure appears to be absent in the SMC and questionable in the LMC (there have been suggestions that the LMC may be a barred spiral) and both Clouds are classed as irregular galaxies, the predicted enhancement in γ -ray flux from the Clouds may not be as great in the absence of clear spiral structure if the latter school of thought is more correct.

Finally, I would like to stress that the fluxes predicted in equation (6) are only a factor of 2-3 below the upper limits set by the SAS-2 observations¹⁵ which give

$$\begin{aligned} F_{\text{LMC}} &< 2.4 \times 10^{-6} \text{ cm}^{-2}\text{s}^{-1} \\ F_{\text{SMC}} &< 1.0 \times 10^{-6} \text{ cm}^{-2}\text{s}^{-1} \end{aligned} \tag{7}$$

Furthermore, the predicted fluxes are well within the capabilities of observation from the COS-B satellite presently in operation. I would urge the COS-B team to attempt detection of these clouds, which would constitute the first detection of extragalactic γ -ray sources. I would also urge a full-sky survey to search for other possible extragalactic γ -ray sources at high galactic latitudes.

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